Constitutive explanations in neuroeconomics: Principles and a case study on money

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Abstract

So far, the methodological debate about neuroeconomics rarely refers to original methodological positions in the neurosciences. I confront one of the most influential ones, the constitutive explanations or mechanism approach, with methodological claims that directly relate the economic model of choice with neuronal embodiments, represented by Glimcher's influential work. Constitutive explanations are composite and non-reductionist, therefore allow for recognizing complex causal interactions between basal neuronal phenomena and cognitive structures, also involving external symbolic media. I demonstrate the power of this methodology in discussing the example of money, which Glimcher posits as one of the most important research tasks in further developing neuroeconomics. Whereas Glimcher justifies neuroscientific reductionism by presenting an evolutionary rationale for deploying formal economic models on particular modules enabling choice, the case of money reveals the need for mechanistic explanations that include a substantial role for cultural evolution, though recognizing causal interactions with basal neuronal mechanisms.

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1. Introduction

In the current methodological debates about neuroeconomics, most contributions concentrate on the relationship between economics and the neurosciences, thus mainly adopting the stance of the methodology of economics (e.g. Harrison 2008; Ross 2012). The original methodology of the neurosciences proper is mostly side-lined. This paper remedies this gap in the current debate presenting the case for constitutive explanations or 'mechanistic analysis' in integrating economics and the neurosciences. Following seminal approaches such as Craver (2007), this is currently one of the most influential methodological paradigms for the neurosciences, so it seems worthwhile to consider its implications for economics. In this assessment, it is important to emphasize the difference between the methodology of the neurosciences (that is, the perspective of philosophy of science) and the implications of the neurosciences for the broader concerns of the philosophy of mind or neurophilosophy (compare Bickle et al. 2012). I am strictly concerned with the former perspective. My focus on this particular approach in the methodology of the neurosciences is further motivated by the fact that the paradigm of constitutive explanations is also unfolding in the social sciences (see e.g. Hedström and Ylikoski 2010; Demeulenaere 2011), thus suggesting a methodological convergence that might also undergird cross-disciplinary integration in neuroeconomics.

I illustrate the implications of methodology for research with a case study, outlining a hypothesis on the neuroeconomics of money. My choice of this case is motivated by the fact that one of the leading researchers in the field, Glimcher (2011: 423f), identified money as one of the most important challenges to neuroeconomic research in stating: "What is the neural organ for representing money?" and: "The algorithmic structure, let alone the identity, of that organ remains one of the greatest mysteries in neuroeconomics today". This is one item in a list of six such challenges, that, as Camerer (2013: 1174) put it, "every graduate student or newcomer to the field should read". Glimcher is also a major contributor to developing a methodology of neuroeconomics which appears to become the standard in neuroeconomics, especially as employed by economists. My aim is to check this methodology against the backdrop of the constitutive explanations benchmark, and demonstrate the consequences with my case study.

My solution to what I call the 'Glimcher challenge' will be exclusively deduced from methodological considerations plugged into a meta-analysis of existing economic and psychological research on money. Surprisingly, I will show that a neglected classic in the theory

of money, Georg Simmel's (1907) 'Philosophy of Money' is highly relevant from the viewpoint of the constitutive explanations framework and thus can guide neuroeconomic research today. I argue that the constitutive explanations framework is particularly powerful in arranging cross-disciplinary research, configuring both the neurosciences and economics in terms of constitutive explanations, and in the next step offer a proposal for integration. My hypothesis on money is an exemplary study pointing towards this possibility, but given the limitations of this paper, I will only sketch the principles of deducing such a hypothesis, serving as an illustration of the methodological issues. So, there is still a long way to go for a full elaboration of this hypothesis as a stand-alone study on money (but see AUTHOR 2014 for further steps towards this direction).

The paper proceeds as follows. I start with discussing an internal methodological tension in Glimcher's (2003, 2009, 2011) methodology of neuroeconomics. Glimcher follows the general stance of mechanistic explanations in the neurosciences, but claims to be able combining this with the axiomatic approach derived from economics that normally is not interpreted as a scheme of causal explanation. In the next step, I argue that the constitutive explanations approach remedies this problem: This proposal agrees with recent assessments of neuroeconomic methodology, especially with Don Ross's 'modular' approach that adopts an externalist standpoint in the philosophy of mind (Ross 2005, 2008). Glimcher also applies modularity as an analytical principle, but claims that the application of economic models on single modules can be grounded in evolutionary analysis, thus reflecting results of adaptation. However, I argue that evolutionary analysis, following the precepts of evolutionary psychology and embedded into a methodology of constitutive explanations, establishes the functional plurality of modules in an architecture of levels of evolutionary processes, most parsimoniously divided into biological and cultural evolution. I continue with my case study, presenting and arranging a number of recent results in the psychology of money, then relating them to Simmel's classical contribution, and eventually condensing these insights in sketching a neuroeconomic hypothesis about money. This hypothesis, which so far is 'informed speculation' with a range of empirical leads, proceeds in two steps: One is a macro-level analysis along the lines of Simmelian psychohistory, based on modern co-evolutionary theories about the relationship between cultural and biological evolution. The other is micro-level analysis of the mechanistic structure that binds the artefact of money together with certain presumed neuronal substrates, mainly following the seminal analysis of Lea and Webley (2006). I conclude with an outlook on the broader implications of the constitutive explanations view for the methodology of economics.

2. Methodological fault lines in neuroeconomic analysis

The methodological notion of 'constitutive explanations' has been developed in the neurosciences, with the seminal synthesis by Craver (2007) that I take as the benchmark for my argument. The starting point in setting up this methodological paradigm is the diagnosis that standard conceptions of scientific explanations in terms of the 'covering law' concept do not work in the neurosciences as guiding principles for explanations (and also for the biological sciences in general, see e.g. Bechtel and Abrahamsen 2005). This is a defining difference between causal and constitutive explanations, as the former refer to general laws in identifying causal processes, whereas the latter highlight the generative power of complex mechanistic architectures which, among other features, can also be singular events or singular historical processes (in detail, see Craver and Tabery 2015; the borderline between the two types of explanation continues to be a bone of contention, see e.g. Ylikoski 2011).

A neuroscience explanation is 'mechanistic' in the sense that neuroscientists identify architectures of mechanisms that work together in generating a particular phenomenon and which manifest different levels of mechanistic constitution (Harbecke 2014). These architectures are at the same time organizing the multi-disciplinary interaction between different disciplines in the neurosciences. So, in explaining a particular behaviour it is necessary to link micro-level research on particular neuronal mechanisms with research on medium-level brain structures and their interaction and ultimately with higher-level cognitive phenomena, including symbolic representations that eventually connect brain processes with social interactions. As an example, consider the interaction of bottom-up and top-down causal analysis in explaining empathetic behaviour (see Singer and Lamm 2009; for this approach, often the term 'social neurosience' is used, compare Oullier et al. 2008): Emphatic behaviour is based on neuronal mechanisms, but its specific forms are triggered by cognitive processes tied up with external symbolic media that identify other persons as possible objects of empathy, such as in-groups vs. out-groups. A fully fledged neuroscientific explanation is therefore multi-level and does not result into the causal reduction of behaviour on basal neuronal mechanisms, even though there has always been an influential strand in neuroscience that advances this claim. As I will argue below, this methodology is particularly powerful in organizing research on complex phenomena such as money, which is a social phenomenon on the one hand, but on the other hand also displays a number of psychological phenomena for which a neuroscientific base needs to be assumed.

This methodological perspective compares with the way how Glimcher states his challenge on money, asking for the 'neural organ' that represents money, and suggesting the possibility of reductionism. Defining the research task in that way matches with the general neuroeconomic program as it is outlined by Glimcher, combining economics and the neurosciences in a way so that economic theoretical concepts and phenomena can be reduced to neuronal phenomena, while also serving as theoretical devices that reveal the abstract principles that underlie neuronal mechanisms. Methodologically, this reductionist view implies that Glimcher aims at transforming the economic 'as if' argument into a 'because' argument (his wording), hence into a causal explanation.

As Camerer (2013) emphasizes in his review of Glimcher's book, this 'neuroclassical' claim is made in the context of neuroscientific analyses of the fundamental process in economics, choice: In fact, most neuroeconomic research up to date is about choices, also connecting up with the corresponding constellation in behavioural and experimental economics (compare Fehr and Rangel 2011). Glimcher posits an economic model of choice, opting for a specification that seems most congenial to neuroscience knowledge about choice and behaviour, which is McFadden's Random Utility model. This particular specification does not matter for my argument, however. The central point remains that the economic model of choice suggests a mathematical structure which relates a value function, dubbed 'utility function', to alternatives under given constraints.

Originally, this economic model is not a causal explanation, however, a fact that is recognized by all serious methodological evaluations of economics. Glimcher refers to the 'as if' instrumentalism of Friedman in his rhetoric, but that seems shaky, given the dismal record of instrumentalism in the philosophy of science (Caldwell 1994). It is more appropriate to recognize the 'revealed preference' approach to the economic theory of choice, that is a mathematical description of observed behaviour which does not make any causal claims about the relationship between an inner psychological state of the individual and her observed choices, i.e. her behaviour (Ross 2005). Glimcher deviates fundamentally from this methodological stance in advancing specific causal claims, positing a physical entity in the human brain that embodies the notion of 'subjective value', and causally explaining behaviour via a number of mechanisms that connect this entity with observed behaviour. For Glimcher this is tantamount to a reduction of the economic model of choice to a neuroscience model. At the same time, that would also imply that the economic model of choice would obtain a law-like role in explaining observed behaviour. Thus, Glimcher's neuroeconomics entails a fundamental shift in the

methodological role of economic theories of choice: They turn into laws that hold for neuronal mechanisms that generate choice as a behavioural phenomenon, and that govern the respective causal relations. That is most succinctly stated by Glimcher and Rusticchini (2004): "The goal of the emerging neuroeconomic program will have to be a mechanistic, behavioral, and mathematical explanation of choice that transcends the explanations available to neuroscientists, psychologists, and economists working alone." How does this position hold up against the methodological yardstick of constitutive explanations?

If we take a closer look at Glimcher's methodological reasoning, it reveals an internal tension, if not contradiction with his actual empirical claims about reduction. Glimcher's original notion of neuroeconomics was not motivated by economic research in the first place. In fact, he introduced economic reasoning into the neurosciences by building on what had been one of the most influential methodological approaches in the neurosciences so far, Marr's contribution (Marr 1982; Glimcher 2003: 133ff; for a lucid summary of this particular argument, see Ross 2005: 323ff). I argue that Marr's approach eventually does not justify Glimcher's claims on reductionism, as it is deployed by Glimcher himself (and not necessarily the original Marr). This is what I identify as internal tension.

Marr (1982) proposed a three-level methodology for the neurosciences and psychology. Level one is approaching a particular phenomenon as a task in information processing, aiming at the design of a computational solution that is generic. This view matched with functionalism in approaching the relationship between brain and mind prevailing at that time (for an overview, see Bickle et al. 2012). Level two specifies the algorithmic mechanisms by which that information processing task, a function, can be realized. Finally, level three specifies the physical mechanisms that realize the algorithms, thus physically representing the solution to the generic function identified on level three. By implication, as with functionalist approaches in general, Marr's methodology allows for multiple realizability, that is, the generic function can be realized by different physical mechanisms, such as a brain, where algorithms are realized by neuronal mechanisms, or computers. Further, the computational theory does not make empirical claims in the first place, but leads research towards the identification of real-world mechanisms. As Dennett (1991: 276f) pointed out, one limitation of this approach is dealing with higher-level, complex and tightly integrated cognitive systems for which no single information-processing task can possibly be defined, a problem that directly applies for Glimcher's neuroeconomic appropriation of Marr's methodology: Choice among two clearly defined alternatives in a stable context (should I drink Coke or milk?) may operate in different

ways than complex decisions about singular decisions affecting entire patterns of behaviour (should I marry this person?) (compare Camerer 2013).

Now, Glimcher goes partly beyond Marr in explicitly embedding this model of neuroscience method into an evolutionary framework, as functions are seen as evolved properties of an organism, i.e. reflecting adaptation along Darwinian lines. In other words, the computational theory would serve to identify the optimal solution of an evolutionary design problem, and the empirical claims are grounded in the assumption that evolution would actually also approach this solution. This is where economics comes into play: The place of economics in the neurosciences is methodologically grounded in evolutionary theory: Firstly, economics offers a computational model of realizing certain functions, with the most general of enabling choice among alternatives. Secondly, economics makes the fundamental forces of selection explicit, namely costs and benefits, although in the evolutionary framework, these are ultimately reduced to differential reproductive success. This implies that following Marr, the role of economics would not be to offer empirical claims about causal patterns in real organisms, but would only identify necessary conditions that any mechanism must fulfil in order to realize an adaptive function.

This is where I see the inner contradiction in Glimcher's attempt at reducing economics to the neurosciences, because Marr's methodology does not imply that the computational model itself has a unique physical realization. In particular, as has also been argued by Ross (2008), economics would relate to real world phenomena in terms of multiple realizability: That means, contrary to methodological individualism in economics, there would not be any pre-determined and exclusive ontological reference of economic theories, which might refer to parts of individuals, individuals, groups or any other entities. It is an empirical issue whether the economic model applies for choices that individuals make. Most importantly, as is also reflected in Glimcher's own applications, economics would probably only apply for parts of individuals, namely the specific modules for which a particular adaptive function can be specified. This corresponds to Dennett's doubts on whether Marr's methodology can apply for higher-level complex cognitive processes, or even the entire person (or, 'consciousness').

We could stop here, because Marr's original approach would put an end to the current debates about the relationship between economics and the neurosciences, partly confirming positions such as Gul and Pesendorfer (2008), but lending another meaning to them. The difference is that in the original Gul and Pesendorfer argument, economics would remain independent from the neurosciences, making attempted reduction otiose, and can directly establish empirical

claims about behaviour as conceptualized in economic terms, along the lines of the revealed preference model (compare e.g. Bernheim 2009). In the Marr view, this independence of economics is confirmed, but at the same time it is denied that economics can make empirical claims on its own, independent from the level of physical realization (which can be neuronal or other). Economics can guide neuroscience research, thus indeed establishing a 'neuroeconomics', but the empirical claims can only be made when completing the entire sequence of steps in the Marr model, that is ultimately detailing the physical mechanisms that generate a particular behaviour.

This argument does not necessarily imply that the specific empirical interpretation of the economic model of choice by Glimcher is misguided. The point is that there is no reason to assume that this is the exclusive way to interpret economics in the context of neurosciences, and secondly, that one cannot infer the empirical validity of the economic model for all kinds of individual-level choices from the possibility of identifying particular neuronal realizations. Applying the economic model successfully on single instances of choice does not imply that entire individuals, as composites of many neuronal mechanisms that would correspond to this description, would also display behaviour that corresponds to the economic model. As we shall see, the central question is whether and how the evolutionary analysis of functions that Glimcher deploys in his use of the Marr methodology indeed only justifies one particular interpretation and application of economics in the neurosciences, namely the 'neuroclassical' version. The problem is immediately salient when pondering the Glimcher challenge: Asking for the function of money in evolutionary terms is evidently very different from asking for the evolutionary function of choice among alternatives.

3. Non-reductionist constitutive explanations as alternative methodological reference for neuroeconomics

I will now introduce the constitutive explanations framework as a methodological alternative to the reductionist Glimcher model. The Glimcher/Marr approach treats the relationship between economics and the neurosciences in terms of levels of realization: The neuronal mechanism realizes the function identified by economic analysis in an evolutionary context. In constitutive explanations, the levels are seen as being constitutive elements of an integral and composite mechanism that produces a particular performance, that is, as levels of composition (Craver 2007: 163ff speaks of a "part/whole" relationship): This makes a fundamental difference even for simplest functions of choice, because it would imply that the levels would

all have the same ontological status, being different physical elements in one integral mechanism of choice. In other words, if we stick to the standard model of economics, the notion of utility would not be reduced to a neuroscience fact and its corresponding entity, i.e. the neuronal embodiments of subjective value, but would maintain a separate role in the entire mechanism of choice. In this interpretation the question would remain meaningful whether the economic model has empirical validity of its own, or, whether it would need to be substituted by other models and their corresponding ontologies. This is one alternative position in current neuroeconomics that would diagnose a tension between the standard economic model and the empirical research in behavioural, experimental and neuroeconomics (Camerer et al. 2005 is the seminal statement on this).

In the constitutive explanations approach, this view can be specified in stating the autonomous causal role of cognitive structures in the mechanism of choice, relative to the neuronal mechanisms that Glimcher scrutinizes. We find strong supporting evidence in Glimcher's own expositions (Glimcher 2011: 383ff). I refer to the fact that the valuations assigned to a lottery, hence involving the formation of expected values with risk, differ depending on whether this formation is mediated via experience or via symbolic representation. Test persons who are asked to evaluate different lotteries based on experiences of sequences of choices end up with a different valuation than test persons who solve the problem of choice in terms of a linguistic representation describing the odds. Most significantly, the two groups display opposite behaviour in terms of the predictions of prospect theory: Test persons responding to linguistic representations show the expected overweighting of low-probability events vis à vis under-weighting of high probability events. In comparison, test persons experiencing sequences of choices show underweighting of low probability events and overweighting of high-probability events. So, choice that is performed in different behavioural terms, driven by cognitive processes (symbolic representation) and even external sequences of events (learning by experience). This defines different physical mechanisms with different composition, in which certain aggregates (such as symbols) exert independent causal power. One cannot reasonably search for one single neuronal substrate that would directly map into the generic computational structure as defined by prospect theory.

These observations reveal that the two behavioural patterns, though based on mathematically identical situations of choice, seem to involve entirely different mechanisms of valuation. In fact, this insight is well-known, beginning with Gigerenzer's (1996) research on heuristics in decision making, and is classically represented by the Wason Selection Task and its

modifications. These results played an important role in establishing the approach of evolutionary psychology which argues against the assumption of one general purpose rationality in explaining human choice (Cosmides and Tooby 2005). The upshot is that the specific representation of choices matters essentially in determining the capacity of individuals in finding optimal solutions, while keeping the computational nature constant (such as the logical structure in the WST). Regarding the representation of probabilities, as in the original Gigerenzer experiments, people appear to be better able to process frequency-based indirect information about probabilities than direct numerical representations. In the WST, individuals were able to correctly apply logical deductions if they were represented as problems of coordination in social interaction, especially identifying cheaters, as opposed to neutral representations of situations of choice. Evolutionary psychologists therefore concluded that the neurocognitive apparatus enabling human choices is actually a complex system of various modules which are adapted to various contexts of choice that are represented in specific ways.

This modular approach to human rationality differs fundamentally from the Glimcher program that aims at the reduction of the general model of choice to the neuronal level and claims that all basal modules can be analysed by the same computational model derived from economics. This is methodologically critical, since Glimcher also refers to an evolutionary argument in justifying reference to the standard model. This matches with a research tradition in ecology and behavioural biology applying economic models in explaining animal behaviour, such as in optimal foraging theory (for a survey, see e.g. Kramer 2001). However, the validity of the economic model depends on the degree of complexity in the situation of choice. As Ross (2005, 2012) has argued convincingly, the economic models may work pretty well when explaining simple actions such as reaching out for a desired object or finding water in a stable environment, but fail in explaining more complex behaviour in the context of social interactions or rapidly changing environments which would require the construction of more complex cognitive models for problem solution.

Now, if we approach this situation from the viewpoint of constitutive explanations, we can translate the evolutionary psychology notion of modularity into the more general notion of the multiplicity of mechanisms in human choice. That would mean that there is not one single model of choice, but different mechanisms linked with different types and domains of choice, which also differ in terms of complexity, patterns of composition and the constituent entities. As we have seen, involving cognitive representations makes a fundamental difference in the performance of choices, so the mechanism differs. Further, many phenomena relevant for

understanding behaviour cannot be analysed in terms of choice, although a mechanistic explanation still holds (one important phenomenon is emotions, see Camerer 2013).

Following Glimcher's original reasoning, and also matching with the evolutionary psychology view, we can now ask how we can apply evolutionary analysis on these composite constituents of mechanisms. Here, we immediately hit on a principled issue in research. One salient example is symbolic representations as media of cognitive processes, which I highlight because our case study on money refers to one particular type of symbolic medium in the context of economic behaviour. The evolution of symbolic representations cannot be directly explained by biological evolutionary models, since they refer to a separate level of evolution, namely cultural evolution. If we approach an animal's foraging behaviour in terms of an economic model, we can reasonably argue that Darwinian selection will lead towards optimization in terms of costs and benefits, since the availability of resources directly relates with differential reproductive success. But this argument rarely applies for the evolution of symbolic media in cultural evolution, as the rise and fall of sociobiology has amply demonstrated. We cannot explore this issue deeper here for reasons of space (done in AUTHOR 2013). Suffice to notice that the rich literature on the co-evolution of biology and culture has shown that the relationship between the two levels of evolution is complex, that the level of culture cannot be fully reduced to the level of biology, and that culture operates as an autonomous element in the human ecological niche, thus also shaping the conditions under which biological selection operates (for overviews, see Mesoudi 2015, and important synthetic approaches Richerson and Boyd 2005 or Jablonka and Lamb 2006).

This literature has important consequences for Glimcher's interpretation of the Marr methodology: We can no longer directly apply biological evolutionary reasoning on identifying the functions of a particular mechanism of choice in humans, and we also need to consider partly autonomous, hence ultimate cultural functions, especially when cognitive structures are involved. In other words, considering the deployment of evolutionary reasoning by Glimcher in interpreting Marr, this appears to be a Trojan Horse that eventually undermines his case for economics as the unifying theory in neuroeconomics.

Considering complex co-evolutionary processes, we can therefore say that the evolutionary psychology view on modular mechanisms needs to be extended to including the role of complex mechanisms involving cultural media as exerting an independent causal role in behaviour. With reference to neuroeconomics, a corresponding methodological position has been developed by Don Ross (2012). Ross argues that human choice essentially builds on externalized cognitive

resources, following the recent literature on distributed cognition and the extended mind (Hutchins 1995, Clark and Chalmers 1998, Clark 2011). His reasoning is mechanistical. He distinguishes between the 'molecular' level of neuronal mechanisms, the 'molar' level of subpersonal cognitive structures that are mediated by external cognitive constructs, and the individual level of behaviour. The economic model can be applied on the molecular level, and depending on the specific nature of the external constructs also on the molar level, but cannot be directly applied on individuals, where the different mechanisms are integrated. In other words, for understanding the behaviour of individuals we need to identify complex composite mechanisms that go beyond the physical boundaries of the organism.

That means, in a constitutive explanations framework we can present strong reasons for applying a distributed cognition approach on human choice (compare Wilcox 2008). In this view, cognitive phenomena can no longer be exclusively reduced to neuronal phenomena because external entities have direct causal relevance for the mechanisms that produce the observed behaviour on the individual level. I will now explore the implications of this view for meeting the Glimcher challenge.

4. Money, mind and brain: A Simmelian perspective on recent research on the psychology of money

Interestingly, in his statement of what I call the 'Glimcher challenge', Glimcher recognizes the fact that the evolutionary reasoning, as he deploys it, cannot directly apply for money, as money evolved in too short a time to allow for a biological explanation. Money is a cultural phenomenon sui generis. As we have seen, this poses a tricky methodological problem in terms of Glimcher's appropriation of the Marr model. How can we construct a hypothetical economic account of money in terms of evolutionary functions that would guide research towards finding those neuronal representations? This is the question that I want to tackle now.

Money is indeed an ideal testing ground for my methodological considerations as it is the quintessentially social artefact, as has been emphasized in philosophical reconstructions such as Searle's (1995, 2010) and Tuomela's (2007). In these reconstructions, no reference to neuronal concepts is made. In spite of the fact that Searle (1995) assumes that, ultimately, rule following must be based on neuronal regularities that produce that behaviour, the institution of money rests upon mechanisms that are fundamentally social in nature, especially in terms of the need for collective intentionality in mutually recognizing the use of money in a population

of actors (for a critical economics view on that, see Smit et al. 2011). That means, however, that there is no necessary convergence between evolutionary mechanisms operating on this level and any kind of biological evolutionary mechanisms. From that point of view, Glimcher's challenge can be seen as resting on a false presupposition: There can be no 'organ' representing money because there is no way to give an evolutionary account of its emergence. The case of money involves a purely autonomous process of cultural evolution. This is the point where Simmel's (1907) 'Philosophy of Money' comes into play.

Simmel's theory of money is based on his general theory of exchange which comes very close to the economic model in emphasizing the role of opportunity costs in choice. However, in contrast to later developments in economics, Simmel thought that exchange is an ontologically autonomous domain in which value is established as an 'objective fact'. Although he assumed that in the first step valuation is a psychological phenomenon, exchange value would superimpose on this, and therefore rationalizes subjective choices. This process of rationalization is an evolutionary, society-wide one. Clearly, a medium of exchange would play a critical role in enabling this objectification.

Consequently, for Simmel money is a social institution that exerts fundamental transformational powers on human thinking and emotions. These powers are independent from the original causes of the emergence of money, which Simmel hypothesizes, like Menger and many others who followed him, to be based on facilitating exchange. However, different from the economic account that became dominant afterwards, Simmel recognized the reverse impact of money on human behaviour. Two dimensions of such impacts matter. The first is cognitive: Money enables cognitive operations such as making values commensurable for any kind of qualitatively different objects, it allows for aggregating values and for dividing them into smallest units. However, these cognitive capacities also go along with emotional transformations, mediated by induced changes of social structures and patterns of social interaction. A central phenomenon is the individualization and abstraction of social categories and relationships, such as separating ownership from personal identity, and enabling an ever growing range of potential choices for individuals.

We do not need to further explore these Simmelian ideas in detail but only concentrate on his central proposition: Money as an artefact exerts far-reaching impacts on human behaviour mediated via psychological transformations. Therefore, we observe the emergence of mechanisms generating behaviours that combine artificial products of cultural evolution with individual-level and probably sub-individual elements of mind and brain. If we interpret this in

terms of neuroeconomic methodology, we immediately realize that the original Glimcher challenge needs to be translated into the question how the top-down causal effects of money interact with bottom-up neuronal mechanisms. As there is no biological evolutionary factor possibly involved here, we have no reason to assume that there is a necessary and unified neuronal representation of money (an "organ"). I claim that this Simmelian perspective on money is vindicated by recent research on money in psychology and the neurosciences.

Interestingly, a Simmelian reasoning has already been deployed implicitly in Dickhaut's et al (2009) concept of 'neuro-accounting'. They argue that accounting is an externalized scaffold which enhances existing brain functions in calculating costs and rewards, especially with regard to criteria such as objectification, comparability or memory. This argument is of interest because it would suggest that the external representation of money would possibly map into a common currency that is deployed in brain level evaluations, at least in the sense of relative costs and benefits of actions (compare Bickle and Landreth 2008). However, this argument approaches money as a cognitive extension, thus does not necessarily imply that money also transforms cognitive and emotional processes, in a Simmelian fashion. For example, Dickhaut et al. think that prospect theory is directly mapped into accounting principles such as valuation according to historical costs, thus realizing losses but not gains. In this case, monetary valuation would not change the underlying neuronal mechanisms. However, reforms of accounting principles in the recent decades have moved to market based valuations (mark-to-market principles, goodwill valuation etc.). Whether this imposition of different accounting principles also changed cognitive and emotional responses, would be an interesting question (for related evidence, see Smith and Dickhaut 2005).

Probably the most fundamental issue here is whether money carries a value on its own. In economic theory, money is mostly seen as a mere transactional tool, without any direct utility like a consumer good. This remains in tension with a practice that neuroeconomics inherited from (much) experimental economics, namely treating money as directly representing value. This is a methodological phenomenon of special interest, as in the original approach of experimental economics, treating money as a linear equivalent to subjective utility, was introduced as a convention that should only apply under certain conditions (Guala 2007). This practice evolved into one of the defining differences between experiments in economics and psychology, yet also diffused into neuroeconomics (Knutson and Wimmer 2007). However, as has been emphasized already by Camerer et al. (2005), this approach appears to be vindicated by neuroscientific research that indicates brain-level phenomena related to money which

directly compare it with other primary reinforcers. That would establish money as a unique kind of artefact, namely a 'culturally conditioned primary reinforcer'.

In fact, one possible approach would be to explain this independent valuation of money in terms of a basket of goods that a monetary unit can buy: In a Pavlovian manner, money would elicit the same responses as this basket (Harrison 2008). That could be reconciled with economic theory, but also would suggest very complex cognitive operations on the part of the subjects, which even would need to converge across different subjects in order to render monetary incentives comparable across different subjects. Interestingly, we would possibly distinguish between the two types of constructing such a basket, one based on a historical sequence of experiences that people individually have with using money in daily operations, the other would be a cognitive operation that would basically look like the economic procedure in generating values of baskets of goods. The former will certainly not lead to convergent 'objectifications' of money, the latter would presuppose that the cognitive operation would actually happen on the collective level.

Probably the most convincing evidence for the independent value of money is the neuroscientific evidence on money illusion that builds on solid psychological evidence (Shafir and Tversky 1997). Money illusion is normally presented as a failure of rationality (an 'animal spirit' in Akerlof and Shiller 2009). But this assessment presupposes that money has no independent valuation, so that the size of nominal amounts of money would not matter, if real values differ in terms of baskets of goods. But money illusion is a proven fact and widespread even among trained groups of test persons. This points towards a Simmelian interpretation, assigning independent value to money. In a much cited experiment, this was supported by fMRI data from subjects replicating a simple behavioural experiment (Weber et al. 2009). BOLD intensities in the reward processing brain areas (ventromedial prefrontal cortex) directly match with the expressed valuations of nominal quantities of money.

However, there is also research that suggests that the activation of monetary representations changes the entire frame of valuations, further confirming Simmelian intuitions (Amir et al. 2008). It is possible to distinguish between subjective utilities (in the sense of revealed preferences) and monetary valuations, showing that the latter do not converge with the former. This distinction is made operational via designing different cues in situations of choice. Cues relating to subjective utilities would make experiences salient (such as experience of heat in theatres), whereas cues for money would activate representations of exchange, such as reference prices or monetary costs of production. If money were an indicator of subjective utility,

reservation prices between the two representations of choices should not differ, but in fact, they do substantially, even suggesting the possibility of welfare losses, as reservation prices in a monetary cue setting are higher than the experience cue ones, thus indicating lost opportunities for exchange.

What these results clearly show is that money activates an exchange frame that is 'objectified' in the Simmelian sense, at least partly decoupled from subjective utilities. This transition adds complexity to the analysis of money effects, as the exchange frame can be further differentiated into different domains of exchange or different perspectives on exchange. This is especially salient in the context of perceptions of fairness, thus directly relating money and exchange (on the following, see Zhou et al. 2014). The special role of exchange comes to the fore when realizing that brain activation patterns differ when people know that they interact with a computer or a human person. Managing money in exchange seems to involve parts of the insula, thus reflecting emotional responses, and cognitive controls, mediated via parts of the prefrontal cortex. This reflects a balance between fairness and self-interest in social exchange, with money triggering self-interest, but the shift towards the exchange domain also inducing emotional reactions cued by perceptions of fairness. Hence, the framing effects of money appear to be complex, indeed. Kouchaki et al. (2013) argue that cues can drift behaviour into the 'business decision frame' emphasizing self-interest and objectification of transactional partners, whereas other cues can also trigger a 'market pricing frame' in which fairness considerations loom large. Cues can be very specific: Qing et al. (2013) show that it even matters whether banknotes are dirty or new and clean: The former trigger selfish and unfair actions, the latter results into the opposite.

The point about these observations is that, on the one hand, money is a source of framing effects, but on the other hand, that these effects are influenced by complementary embedding frames which define the specific domain in which money use occurs. The framing effects of money are a well-established fact for decades, beginning with Titmuss's classical work on blood donations. These effects have been generalized in the literature on social preferences, with now many examples showing that a transformation of incentives into monetary ones often shifts the frame towards a market pricing one (survey in Bowles and Polonía-Reyes 2012). For example, what is a moral commitment in one frame, would turn into a fine in another frame. As in the original Titmuss example with positive incentives, the highly suggestive observation is that the transformation is not neutral vis à vis the original incentive: From the standard economic point of view, if people perceive a moral obligation, hence a negative incentive for an action, this

should only be reinforced by adding a fine, which is also a negative incentive. But in fact the monetary fine introduces a frame shift: The fine might be perceived as a price to be paid for actually allowing the action, hence rendering the moral commitment non-binding or even providing moral legitimacy to the action, as it is paid for.

These framing effects of money have been demonstrated in a series of priming experiments that compare behaviour with and without a money prime (Vohs et al. 2006, 2008) and which directly confirm many of the original Simmelian intuitions. Priming people with money results into significant alterations of behaviour, such as not helping others in picking up spilled materials in the lab, or in placing oneself in larger distance to others. Other experimental evidence suggests that money directly interferes with emotion regulation, especially in social interactions: People tend to be less willing to express and also recognize stronger emotions, both in themselves and others, after having been primed with money (Jiang et al. 2014). There are also effects on higher cognitive levels: Caruso et al. (2013) show that Americans primed with money shift political valuations towards the pole of free markets and approving of social inequalities. Interestingly, this does not happen when dollars as a money sign are used with non-Americans.

To summarize, recent psychological research on money has clearly vindicated Simmel's original ideas about the transformative powers of money: Money cannot be simply approached as an expression of more fundamental psychological phenomena, and also cannot be only approached in a purely instrumental way, but it exerts strong causal impact on human cognitive and emotional processes. Accordingly, in a constitutive explanations framework, we need to envisage a complex multi-level and composite mechanism in which money as an artefact obtains an ontological autonomous position as a causal factor. This shows the way how to meet the Glimcher challenge, and proceeds in two steps: The first is to establish the co-evolutionary framework, the second is to sketch a possible microstructure.

5. Co-evolutionary approach to the emergence of money and functions of money

In the following two sections, I present a mere sketch of a possible neuroeconomic approach to money designed along the lines of a constitutive explanations methodology. So, my focus is not presenting a theory of money in sufficient detail and comprehensiveness so that this particular version would be fully vindicated in empirical and theoretical terms. My only aim is to present one possible version that illustrates how the methodological principles can be put at work, thus

also demonstrating the limitations of Glimcher's methodology of neuroeconomics (hence, this is a 'mechanism sketch' in the sense of Machamer et al. 2000).

One most important insight transpiring from the research reviewed in the previous section is that money appears to be closely related with social exchange, not only in the sense that it is a medium of market exchange, but that it triggers shifts towards broader cognitive representations of exchange in which markets are only one special form. As we have seen, money therefore may trigger different effects, especially in the context of perceptions of fairness vs. self-interest. This leads us to consider one idea that Glimcher briefly mentions in posting his challenge, namely that money relates with a pre-existing neuronal module that enables social exchange in general. However, Glimcher does not refer to the pertinent literature here. Indeed, this idea would immediately lead into a fundamental conceptual tension between the modularization thesis in evolutionary psychology and the Glimcherian position that upholds the universal economic model of choice as a reference for analysing neuropsychological foundations of behaviour. One way to make sense of the psychological research overviewed here is assuming that money triggers different modules of choice, depending on various contexts.

In fact, Glimcher's guess is already elaborated in much detail by Lea and Webley (2006) (which he does not cite). The authors elaborate on the two interpretations of 'money as a tool' and 'money as a drug', with the latter suggesting independent causal impacts of money on behaviour. However, implicit reference to addiction is problematic, although it raises the important question how far in certain institutional contexts (such as stockmarkets) addiction to gambling may play a role which involves monetary incentives. Addictive gambling is seen by Ross et al. (2008) as the purest case of addiction as it presumably builds on a loss of control of dopaminergic circuits in the brain, thus triggering behaviours towards goal attainment without actually achieving fulfilment, yet leading to enhanced levels of dopamine which is the 'real' object of addictive craving. Other elements of explanations of addictive gambling can be aligned with this view, such as the role of 'illusion of control', see Clark (2010). So, the central factor in addictive gambling is not money per se, but the special context of activities of goal attainment in general, and the related learning processes (Redish et al. 2008). Yet, as money is an especially strong incentive, it might be strong trigger of switching towards addictive behaviour. So, what is more important is explaining the independent role of money as a strong incentive.

The drug metaphor comes up when Lea and Webley argue that money 'piggybacks' on a social exchange module in the human brain. They start out from the aforementioned evolutionary

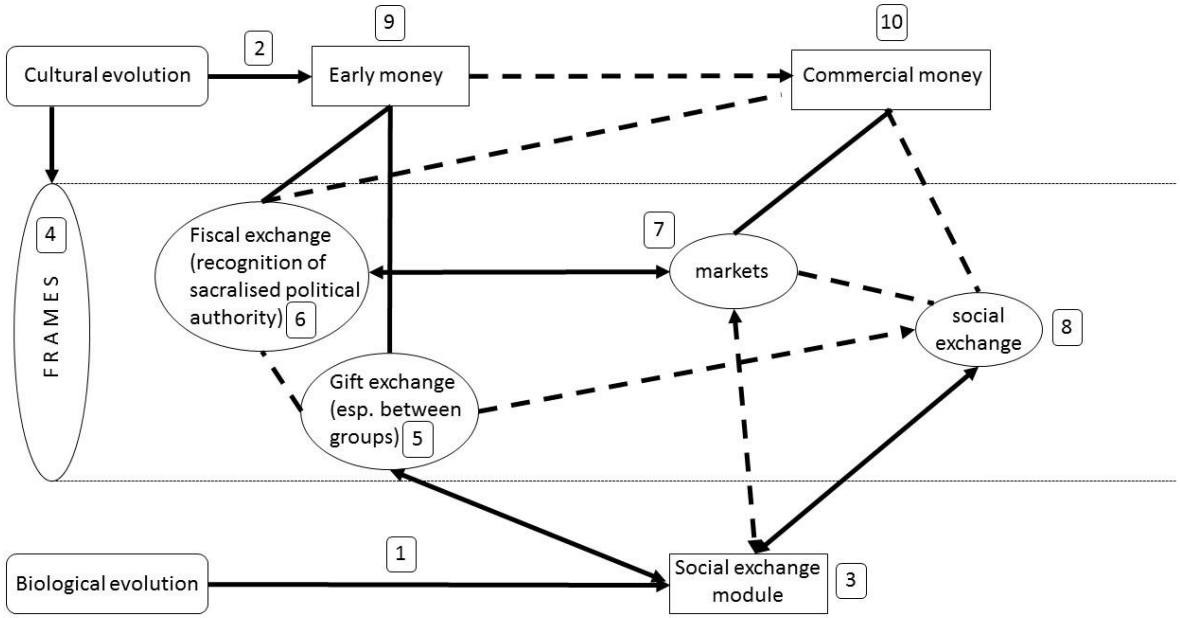
psychology view on the existence of such a separate decision module (a 'cognitive instinct' à la Pinker). The central point is that in such a decision module, social exchange would be evaluated as a specific source of gratification. This matches with research showing that cooperation in humans triggers the standard dopaminergic reward mechanisms. Interestingly, this vindicates early ideas of Adam Smith (1759) in the 'Theory of Moral Sentiments', arguing that 'fellow feeling' is an autonomous source of pleasure (Sugden 2002). In this view, cooperation is not 'sacrificing' individual interests but actually is translated into the standard currency of reward, thus unifying different degrees of 'individual' vs. 'social preferences' (Fehr 2009). This matches with other research showing, for example, that social punishments are also a source of dopaminergic gratification (Bowles et al. 2003).

I propose to systematize these observations in referring the notion of the 'value of money' to an emotional complex related to social exchange which enables rational decision making in the sense of Damasio's (1997) theory of somatic markers. This notion combines reference to composite structures and more basic neuronal embodiments of values, the somatic markers (Reimann and Bechara 2010). This is most obvious in the classical experiment showing the relevance of the theory, the Iowa Gambling Task, where money representations unequivocally trigger the non-cognitive capabilities of valuing different decks, thus possibly revealing its causal connection with a somatic marker. So, we might surmise that money works together with a pre-existing 'social exchange module' with specific somatic markers generating peculiar emotional patterns, as anticipated by Simmel and confirmed by recent experimental research. In evolutionary psychology, emotions are aggregate patterns of behaviour and correlated neurophysiological mechanisms that coordinate the more basal mechanisms such as the dopaminergic circuits with other mechanisms that work together in eliciting regularized actions towards external stimuli (Tooby and Cosmides 2005).

If we now look at the evolutionary foundations for this analysis, the distinction between cultural and biological evolution is essential for giving a more precise meaning to the notion of 'piggy-backing'. This is where we can combine constitutive explanations in social sciences and the neurosciences, resulting into a single framework of historical mechanistic explanation (Demeulenaere 2011) that ties up with basal hypotheses about neuronal embodiments. I try to overview the complex interdependencies in fig. 1, where I distinguish between the two autonomous processes, biological (1) and cultural evolution (2). Biological evolution gives rise to the emergence of a social exchange module (3) (following recognized theories about the 'social brain', see Frith 2007; Dunbar and Shultz 2007). Cultural evolution is conceived as the

evolution of artefacts and symbolically mediated frames (4) which define certain domains of interaction and patterns of meaning. In figure 1, these domains are 'gift exchange' (5), 'fiscal exchange' (6), 'markets' (7) and 'social exchange' (8). I posit a distinction in the evolution of money artefacts, namely between 'early money' (9) and 'commercial money' (10), with the former related to gift exchange and the latter to markets. The broken line indicates that there is no direct evolutionary trajectory linking early money and commercial money, as they relate to entirely distinct frames and domains of interaction (in detail on this point and the following, see Hénaff 2002).

Fig. 1: The co-evolutionary mechanisms of the emergence and use of money



Co-evolution means that bi-directional causal linkages emerge between cultural and biological evolution, so the diagram sketches a historical mechanism. This view questions the standard economic explanation of the emergence of money that sees a continuity between early and commercial money and explains money in terms of transactional needs of barter. In fact, we need to distinguish two domains: One is the domain of reciprocity in mutually recognizing group identities via the exchange of gifts, which is historically manifest in so-called 'primitive' or 'early money': The evolutionary hypothesis links this with the biologically grounded social exchange module (3-5-9). The other is the use of money in market relations, which needs to be

further divided in the fiscal uses of money as a form of paying taxes (10-6), and the use of money in commercial relations (10-7). However, the fiscal use of money partly also overlaps with the domain of gift exchange, in the sense that paying taxes is framed as contributing to a higher level authority with partly sacral features of representing the community and cooperation; often, tax duties were also not calculated in terms of the monies used in commerce (cf. Ingham 2000; Chavas and Bromley 2008). So, taxation represents an evolutionary phenomenon of its own (5-6-9-10). Historically, fiscal uses of money were triggers of marketization, for example via the payments for armies (6-7) (Graeber 2011). Accordingly, coinage very early received the recognition and hence ritual sanctification by political authorities, thus closely interacting with the diffusion of coins driven by commerce (Hutter 1994). So, in cultural evolution we clearly discern the duality of the merely instrumental use of money and the uses which would indicate an intrinsic value of money. After markets expanded, such that commercial money crowded out early money as a ritual artefact, the traditional domain of gift exchange morphed to the domain of social exchange (5-8), in which money might also be involved, yet in a different frame and often highly circumscribed, often even in the sense that social exchange would be spoiled if involving money (Zelitzer 1997; Sandel 2013) (10-8-3).

I posit that it is the latter phenomenon that establishes the causal interdependence between a social exchange module and money. In terms of my Simmelian psychohistorical hypothesis, this would establish a direct mechanistic connection between early money and the social exchange module. This connection would continue to hold in the context of social exchange, however, it is thinned out in relation to commercial money. This transpires if we consider the further cultural history of money. One important observation is that the instrumental use of money was entangled in complicated moral and religious frames right from the beginning, introducing taboo areas, creating severe tensions between moral norms and actual practices, and also often degrading commercial activities to ‘necessary evils’ in many societies, including Western Europe (Walsh and Lynch 2008). It is illuminating to relate this observation with the previously mentioned experimental results which show that money is not unequivocal in terms of framing. We can now argue that triggering fairness considerations matches with the original social exchange meaning of money, whereas triggering ‘egocentric’ behaviours matches with the commercial frame. In the current conceptual framework, it is the former that is the basis for the independent valuation of money, as suggested by Lea and Webley.

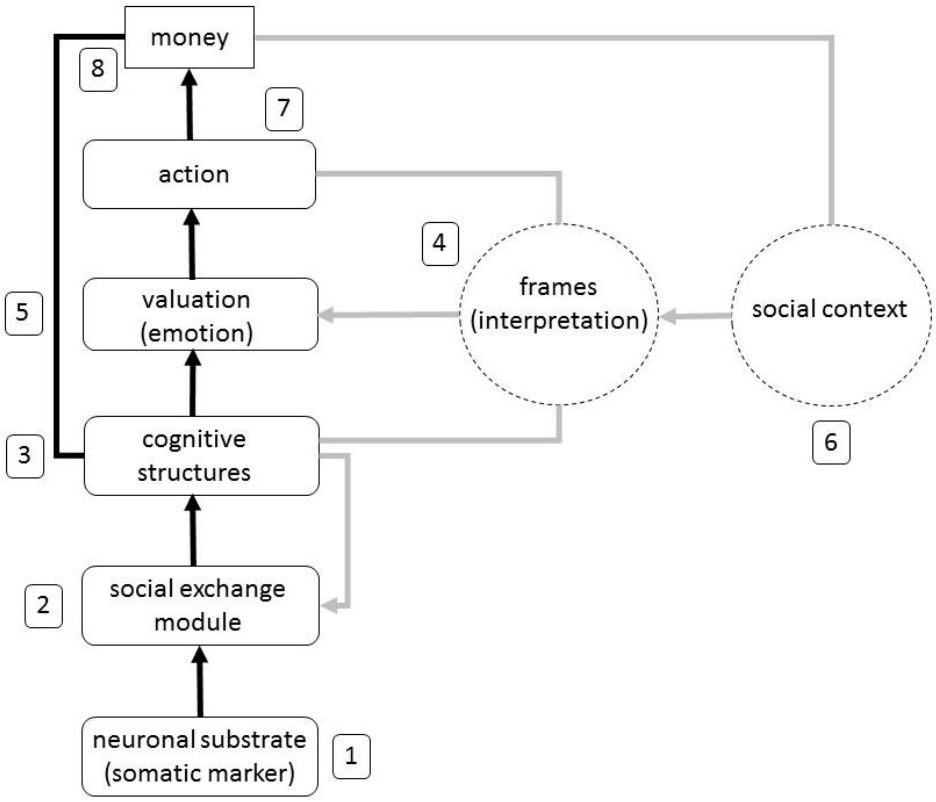
Therefore, if we consider modern money, ‘piggybacking’ means that money, given the fluidity and fuzziness of the borderlines between the frames of social exchange and markets, partly

triggers the social exchange module, and thus activates the corresponding somatic marker and gratifications. For detailing this hypothesis, we need a micro-level conceptual framework that I explore in the next section.

6. Micro-level mechanisms: Artefacts and brain

In fig. 2 I present a hypothetical neuroeconomic approach to money that includes composite mechanisms and ontologically diverse elements emerging from the co-evolutionary process that I sketched in the previous section. As has been emphasized by Bechtel and Abrahamson (2005), one appropriate way to present mechanistic explanations is diagrams. In such a diagram one distinguishes between the constituent elements of the mechanism and the different kinds and directions of constitutive relations, which can be compositional or causal (again, this is a mechanism sketch in the sense of Machamer et al. 2000). The solid black lines show direct physical relations, which would correspond to a reductionist approach, if seen in isolation: The neuronal substrate (1) arranges into a social exchange module (2) which enables cognitive structures (3) processing valuations (5) that are being enacted in physical actions (7), involving the physical artefact of money (8). This establishes a compositional structure that would suggest the possibility of reduction, on first sight. The first divergence from the simple reductionist model is the direct physical connection between the money artefact and the cognitive structure (8-3): Money is an external constituent part of the latter. On the other hand, the grey solid lines show relations which are physically mediated but where the relations are more complex in manifesting functional interdependencies ultimately tying up with social context (6). The first is the feedback between cognitive structures and the underlying neuronal substrates (3-2), as they activate the latter depending on the perception of action contexts, hence mediating the frames in internal brain processing. Frames directly impact on the valuation in positing valuations in particular social contexts (4-5). This happens via the materialization of valuations in actions, thus in fact triggering processes of social learning that result into certain behavioural regularities (7-4-3-5). So, we see that there is a ‘hard’ physical structure of the mechanisms and a ‘soft’ structure of functional interdependencies. Money is ambivalent here, as money is a product of cultural evolution, so originates from social context in the most general sense.

Fig. 2: Micro-level mechanisms related to money



In more detail, different from the Glimcher methodology, but partly receiving its insights, the starting point is the idea that observed behaviour (action) is causally related with neuronal substrate, which I have identified as a somatic marker (1). This also follows the general presumption of ontological monism and naturalism that posits that the entire mechanism is defined in physical terms (Papineau 2009). As a result of biological evolution, the neuronal substrate is organized into domain specific modules that underlie valuation, which I call the social exchange module (2), following evolutionary psychology. The social exchange module is embedded into larger cognitive structures (3) of the human brain that enable the complex operations of valuation based action, both habitual and conscious. These structures are causally integrated with external artefacts, resulting into culturally conditioned frames (4).

As we have already seen, on this level I posit the first causal feedback loop between different parts of composite mechanisms, since the cognitive structures are involved in triggering elements of the neuronal substrate. This effect, however, must be understood in the context of the entire architecture. Cognitive structures enable valuation (5). Following Damasio, valuation is emotionally grounded, but that must be neatly distinguished from the causal force of somatic

markers in the neuronal substrate. Emotions are aggregate mechanisms that involve interactions with frames that originate extra-somatically, namely in the social context (6). For example, whether a certain social interaction triggers certain emotional responses depends on how it is interpreted; however, the interpretation is not just an individual action but depends on socially transmitted frames by which the action is given a particular meaning, and in which triggering a frame is incited by external determinants, especially actions of others. This relates, for example, to societal notions of taboo areas for the use of money.

Following recent theories about grounded cognition (Barsalou 2008), it is essential to notice that this framing depends on the action taken (7). It may have been transformed into an inner state, but that goes back on the internalization of actions and the historical sequence of experiences related to these actions. Hence, the causality underlying the framing effects is only covered completely in a social learning framework that is also part and parcel of theories of cultural evolution (Richerson and Boyd 2005). So, framing is actually interpretation of actions, mediated by social contexts.

To sum up, the sketched micro-structure of money undergirds the evolutionary processes analysed in the previous sections. One important implication is that the Glimcher challenge is actually meaningless: There cannot be a single 'organ' that represents money, in spite of the fact that money is mechanistically connected with neuronal phenomena. Money as an artefact is contextualized and activates different mechanisms depending on the specific framing. As I have argued elsewhere (AUTHOR 2012), money is therefore 'performative': In spite of the fact that the artefact is a physically homogenous phenomenon, the behavioural phenomena related to money root in various and distinct mechanisms that combine externally generated frames with basal neuronal structures.

7. Conclusion

In this paper I have shown that a constitutive explanations framework can be a powerful methodological approach in integrating the neurosciences with economics. In conclusion, I emphasize one result that is so far only implicit: In the debate over different interpretations of neuroeconomics, I side with the tendency represented by Camerer, hence arguing that behavioural and neuroeconomics will also require a major revision of the basic economic model of human choice, against the Glimcher view that neuroscience actually can vindicate a modified standard model. However, so far the problem with this position is that it appears to be eclectic

and fragmented: Behavioural economics is a collection of effects, behavioural phenomena and specific hypotheses which cannot be integrated into one coherent model that would successfully substitute for the standard model. This is the typical situation described in the Kuhn and Lakatos tradition of understanding scientific change and innovation: Even a large number of falsifications will not lead to a change in fundamental theory, unless an equally powerful alternative theory is available.

I think that the dilemma is that the methodological standards in evaluating the alternative theory are still derived from the ideals of the standard model: elegance, consistency, formal simplicity and so on. Against these ideals, the new behavioural economics and neuroeconomics appears to be messy. Glimcher's 'neuroclassical' theory offers the promise to maintain the old standards in an attempt at integration. However, if we introduce the constitutive explanations approach from the life sciences into the debate, a methodological deus ex machina, things turn out to be very different.

At the same the same time, however, we also realize that one dilemma of neuroeconomics and behavioural economics is that most analyses still adhere to the standard approach in identifying actual behaviour as a deviation from the model of rationality. In this sense, the new approaches contribute to the resilience of the standard model, in particular when we consider normative applications such as in the context of 'nudging' people towards the 'right choices'. Here, we can productively take up one principled aspect of Glimcher's methodology: This is to refer to general evolutionary theory in systematizing observed phenomena and achieving generalized explanations: the identification of mechanisms of choice, especially in terms of a taxonomy of types, would be based on theories about co-evolution. My discussion of the case of money shows how this approach could be made operational.

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